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REGIONAL SEISMOLOGY IN ARGENTINA

FINAL TECHNICAL REPORT

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20. Abstract

An orientation study on regional seismology in Argentina reveals extensive actual and projected seismometry. Data digitization is being initiated at some stations, and modern computing systems are being acquired. Most of the regional seismicity is explained in terms of the subduction of the Nasca plate under the South American continent, but also intraplate earthquakes have occurred. Part of the subduction, initially with a dip angle of 30° (deg), is horizontal. Seismicity gaps exist in the Province of Tucumán, and in depth between 350 and 500 km. Source parameters

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for the Salta, 1973 and Caucete, 1977 earthquakes are reported. Refraction profiles suggest complex velocity structures in the earth's upper 6 km.

Short-period noise levels vary more than 30 dB with local geologies. Micro-seismic storm long-period energy is mainly between 5 and 10 seconds periods. Negative first motion on Argentinian P-waves from Nevada Test Site presumed underground nuclear explosions may indicate tectonic strain release associated with these events. Primary Eurasian event signals are PKP-waves, in correspondence with standard travel time vs. distance curves. Signal arrivals between P- and S-waves seem to be P- to S-wave and S- to P-wave conversions on the lithosphere-asthenosphere boundary, according to the literature, suggesting thatthis boundary may be at a depth of 400 km.

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ABSTRACT

An orientation study on regional seismology in Argentina reveals extensive actual and projected seismometry. Data digitization is being initiated at some stations, and modern computing facilities are being acquired. Most of the regional seismicity is explained interms of the subduction of the Nazca plate under the South American continent, but also intraplate earthquakes have occurred. Part of the subduction, initially with a dip angle of 30°, is horizontal. Seismicity gaps exist in the Province of Tucumán, and in depth between 350 and 500 km. Source parameters for the Salta, 1973 and Caucete, 1977 earthquakes are reported. Refraction profiles suggest complex velocity structures in the earth's upper 6 km.

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Discussions with Argentinian seismologists, in particular F.S. Volponi, S. Gershanik, J.S. Aguirre Ruiz, J.C. Castano, E. Jashek, and their supply of data were instrumental in obtaining the information used in this report. AFOSR invitational travel, and a NORSAR travel grant made possible attendance and presentations at meetings outside Argentina.

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SECTION I
INTRODUCTION

This Final Technical Report describes the work performed under AFOSR Contract No. F49620-79-C-0098, during the contract period 1 May 1979 - 30 September 1980. The work concerns an orientation of available research facilities, and research on topics of regional seismology in Argentina in the context of worldwide seismic surveillance.

A brief summary of the work performed during the first year's period, 1 May 1979 - 30 April 1980, was issued previously as Annual Technical Report No.1. This comprehensive report describes the research, based on literature, personal communication, and some actual data, in Section II. Topics include: seismicity, source characteristics, propagation velocities, noise, and signal characteristics. Also included is a summary of a publication concerning previous research on the automatic detection, timing and identification of seismic event signals. Conclusions, and suggestions for future work are presented in Section III. Section IV contains the related bibliography.

SECTION II
RESEARCH

A. INTRODUCTION

This section describes the research performed during the contract period concerned. First, we present an overview of available research facilities in Argentina. Next, we treat the topics of regional seismicity, source characteristics, propagation velocities, noise, and signal characteristics, as found from literature research, personal communication, and seismic data. The final part summarizes a refinement of previous research which resulted in two publications.

B. RESEARCH FACILITIES

The major research facilities in Argentina are provided by the Instituto Nacional de Prevención Sísmica (INPRES, National Institute of Seismic Surveillance). The objectives of this institute are enhancement of seismological studies, design of earthquake resistant building codes, and national representation in seismology and earthquake engineering matters. INPRES is responsible for the installation and maintenance of national networks of seismographs, strong-motion accelerometers, and seismoscopes (INPRES, 1979). The projected seismograph network is presented in Figure II-1. Short-period seismometers are S-13, Benioff or Wood-Anderson; long-period seismometers are Press-Ewing. The network includes a telemetered four-station, vertical component short-period array of approximately 25 km radius at San Juan. The INPRES strong-motion accelerometer network counts 18 three-component Ishimoto instruments, to be augmented with another ten during 1980. The INPRES seismoscope network

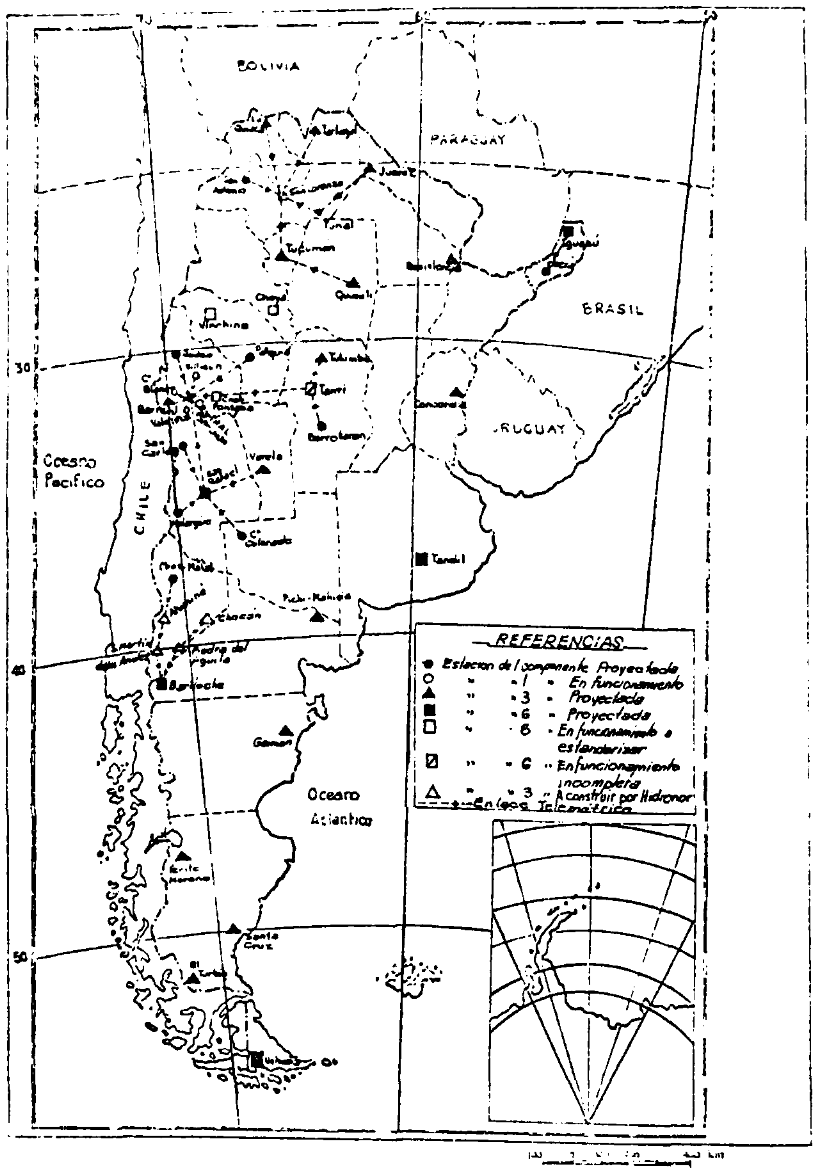


FIGURE II-1

NATIONAL SEISMIC NETWORK OF THE REPUBLIC OF ARGENTINA (INPRES, 1979) consists of 114 seismoscopes, to be augmented with another 50 during 1980.

In addition to the operation and maintenance of the above mentioned instruments, INPRES performs special project seismicity and seismic risk studies, for instance, for nuclear and hydroelectric plants.

Besides the INPRES network of seismic stations, there are the six-component WWSSN station at La Plata (LPA), the stations CEN and ZON operated by the seismological institute ZONDA of the University of San Juan, and some seismographs at meteorological stations. Station CEN is a remote station consisting of a vertical component, short-period seismograph; ZON has E-W and N-S horizontal component mechanical short-period seismographs, a vertical component short-period seismograph, and a 50-second E-W horizontal component long-period seismograph. No data could be obtained for the meteorological station instruments.

The University of Tucumán maintains an experimental geophysical station 20 km West of the city of Tucumán, in the foot of the Andes mountains. Instrumentation consists of a magnetometer, pendulums, and a short-period vertical component seismometer with a frequency response peaking at 1 Hz. Technical problems so far have prevented the seismograph to be operational as a seismic station; it is expected that its function will be restored shortly.

Seismometers at the various seismic stations typically are placed in a vault at the end of a horizontal tunnel dug in rock, approximately as sketched in Figure II-2. Seismograms are recorded on smoked or thermal paper, the former giving a considerably higher resolution.

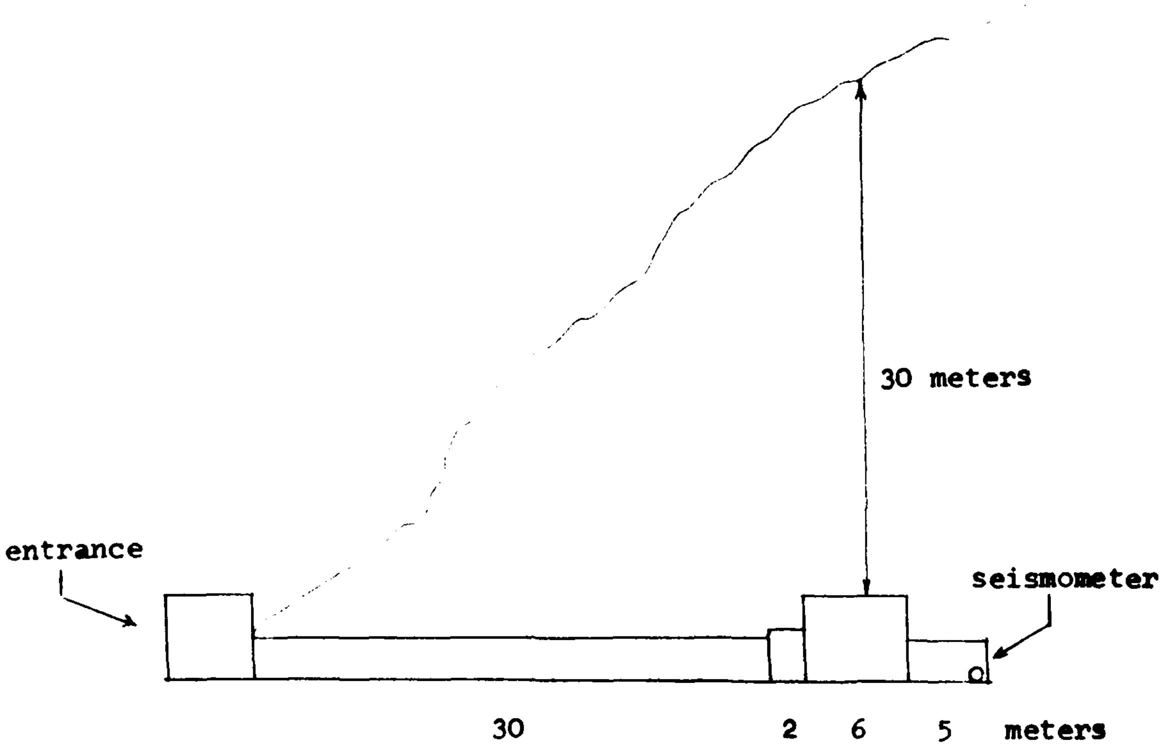


FIGURE II-2
UNT SEISMOMETER PLACEMENT

Both INPRES and the University of Tucumán (UNT) are in the process of acquiring modern computing facilities. The INPRES system is Hewlett-Packard with tape, disk, diskette and cassette capability, and a digitizing table for digitizing analog seismograms. The UNT facility is a Digital Equipment Corporation (DEC) VAX-11/780 system with disks and tape, and employing intelligent terminals with diskette (floppy disk) capability.

Finally, the following organizations provide regional seismology literature:

- INPRES: reports and publications, seismic bulletins
- Asociación Argentina de Geofísicos y Geodestas (Argentinian Association of Geophysicists and Geodesists, AAGG): Geoacta, professional journal.
- Instituto Panamericano de Geografía e Historia (Panamerican Institute of Geography and History, sponsored by the Organization of American States: Revista Geofísica (Geophysical Journal).

B. SEISMICITY

The seismicity in Argentina is determined mainly by the relative tectonic movements of the Nazca Plate and the American Plate, and, in particular, by the subduction of the former under the latter, Figure II-3. Summarizing the tectonic movements affecting the Argentinian territory (Volponi, 1974, 1979), it is assumed that convection currents thrusting upwards at the Mid-Atlantic Ridge cause the African Plate to move eastward, and the American Plate westward, both at a velocity of 2 cm/year around 30° S latitude. The Nazca Plate appears to be moving eastward at 6 cm/year, thus

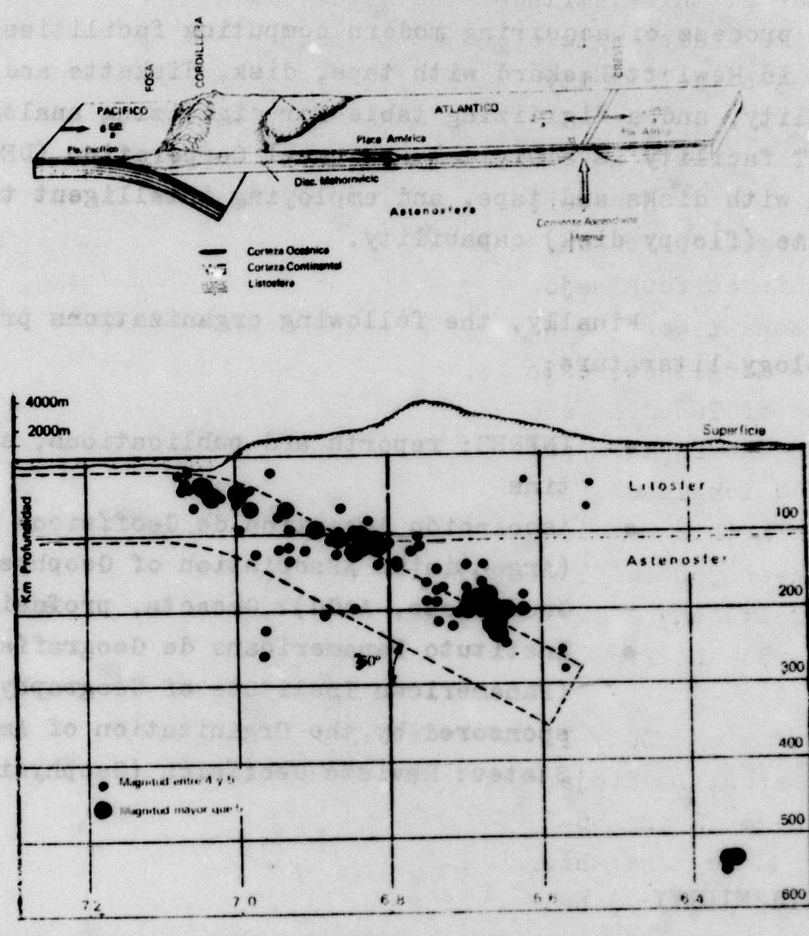


FIGURE II-3

TECTONIC MOVEMENTS AFFECTING THE ARGENTINIAN TERRITORY

(Volponi, 1974)

colliding with the American Plate at a relative impact velocity of 8 cm/year at this latitude. The Nazca Plate underthrusts the American Plate with a dip angle of 30° with respect to the horizontal, as evidenced by seismicity patterns.

However, the subduction in South America does not seem homogeneous (Duda, 1976; Volponi, 1974, 1979). Volponi (1979) distinguishes four major zones for the Argentinian territory (Figure II-4). Zone I, or the Northern Zone, between 18-26° S latitude and 63-72° W longitude, extends from Southern Peru to the Argentinian Province of Tucumán, and covers parts of Northern Chili and Southern Bolivia. The Eastern part of this zone, named Zone I', between 63 and 65° W longitude, contains the deep-focus earthquakes (500-700 km depth). In this Northern Zone, the Benioff zone shows a seismicity gap between 350 and 550 km depth. Seismicity in this zone is highest in the Salta and Jujuy provinces, near the Bolivian border, and tapers off towards the Province of Tucumán.

Zone II, or the Central Zone, comprises the provinces of Catamarca, La Rioja, San Juan and Mendoza, South of Tucumán, between 26-36° S and 66-73° W. The seismicity here is less than in the Northern Zone, and shows specific characteristics (Figure II-5). The seismicity produced between 30 and 34° S latitude shows that the dip of the Benioff zone changes around 70.5° W longitude from 30° to horizontal. Eastward of this longitude the seismicity seems to be concentrated at approximately 120 km depth. These characteristics are similar to those of central Peru (Hasegawa and Sacks, 1980).

Zone III, or the Patagonic Zone, covers the area south of 36° S latitude, comprised by the Pacific Ocean near the Chilean coast, Chili, and Western and Southwestern Argentina. This zone is characterized (Volponi, 1979) by the absence of intermediate depth

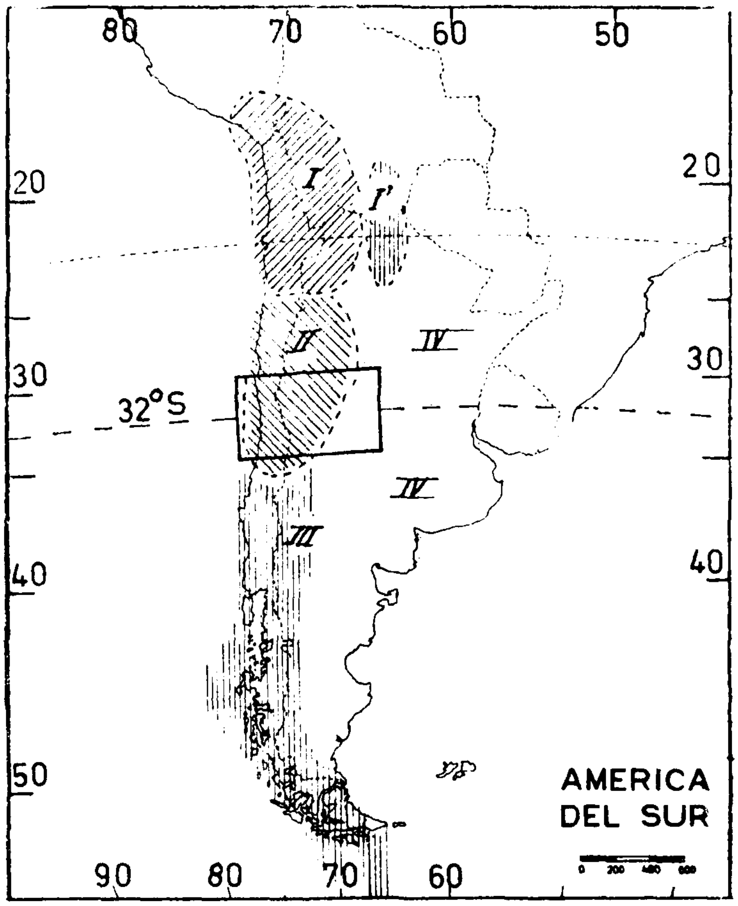


FIGURE II-4
THE FOUR LARGE SEISMIC ZONES FOR THE ARGENTINIAN TERRITORY
(Volponi, 1979)

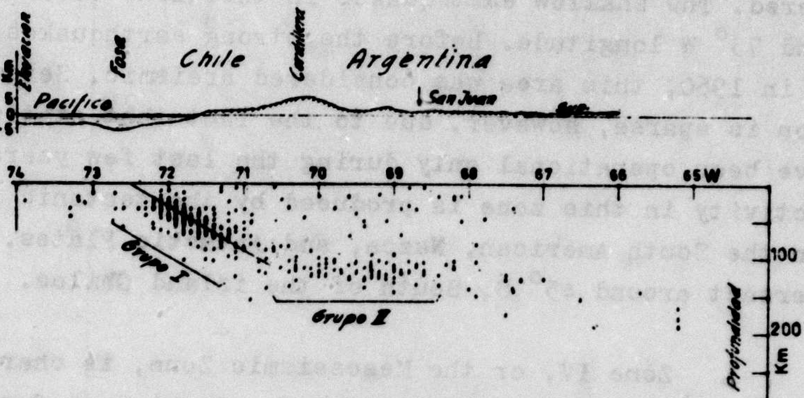


FIGURE II-5

SUBDUCTION BETWEEN 30° AND 34° SOUTH LATITUDE, AS EVIDENCED BY PROJECTIONS OF HYPOCENTERS ON VERTICAL PLANE (Volponi, 1979)

earthquakes. Rarely an earthquake with a depth greater than 70 km is registered. The shallow earthquakes in this zone occur in general around 75° W longitude. Before the strong earthquakes of Southern Chili in 1960, this area was considered aseismic. Seismicity information is sparse, however, due to the fact that stations (in Chili) have been operational only during the last few years. The seismic activity in this zone is produced by the tectonic interactionbetween the South American, Nazca, and Antactic Plates, which intersect around 45° S, South of the island Chiloe.

Zone IV, or the Mesoseismic Zone, is characterized by 13 intraplate earthquakes, Figure II-6, of which no further details were reported in the literature studied.

Concerning the Tucumán area, this province seems to exhibit a seismic gap. It is not known if this area is aseismic, is subject to seismic creep, or if stresses are accumulating for a future tectonic energy release. In a study of seismicity affecting the Tucumán province, and covering the area $25\text{-}29^{\circ}$ S, $64\text{-}67^{\circ}$ W, Zossi (1979) found that most of the seismicity was concentrated at 28° S, between 66 and 67° W, and in depth at about 170 km. This area of relatively high seismicity shows special geological features in that it seems to be comprised of a depressed, northward dipping block.

Some of the seismicity data presented above were compiled from historical data, going back as far as the year 1692. Table II-1 gives an overview of the most important destructive earthquakes. Where necessary, magnitudes were estimated from intensity vs. distance curves, Figure II-7, obtained from observations and historical descriptions.

Figure II-8 shows the maximum intensities observed in Argentina until 1976. Figure II-9 presents a seismic risk map for the Argentinian territory calculated by INPRES (1978).

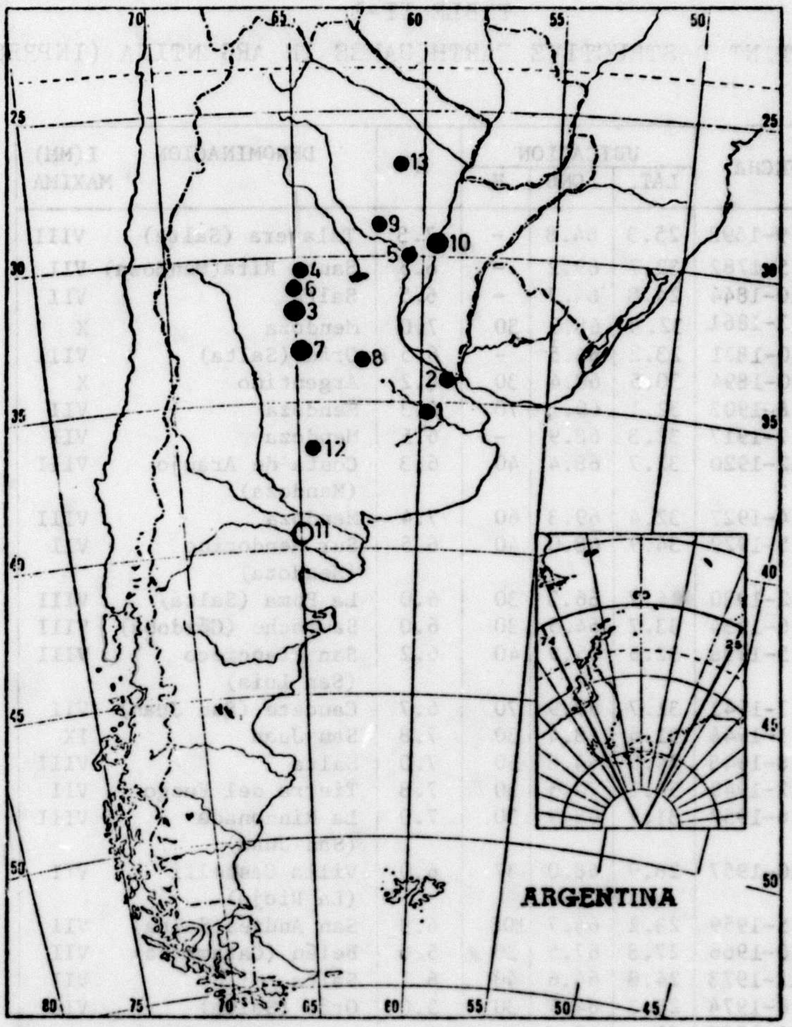


FIGURE II-6

MOST IMPORTANT EARTHQUAKES IN ZONE IV, 1845 - 1968 (Volponi, 1979)

TABLE II-1

MOST IMPORTANT DESTRUCTIVE EARTHQUAKES IN ARGENTINA (INPRES, 1978)

FECHA	UBICACION			M	DENOMINACION	I(MM) MAXIMA
	LAT.	LONG.	H			
13- 9-1692	25.3	64.8	-	7.3	Talavera (Salta)	VIII
22- 5-1782	32.7	69.2	-	6.5	Santa Rita(Mendoza)	VII
18-10-1844	24.8	64.7	-	6.5	Salta	VII
20- 3-1861	32.9	68.9	30	7.0	Mendoza	X
22-10-1871	23.2	64.5	-	6.5	Orán (Salta)	VIII
27-10-1894	30.5	68.4	30	8.2	Argentino	X
12- 8-1903	32.1	69.1	70	6.3	Mendoza	VII
26- 7-1917	32.3	68.9	-	6.5	Mendoza	VII
17-12-1920	32.7	68.4	40	6.3	Costa de Araujo (Mendoza)	VIII
14- 4-1927	32.4	69.3	60	7.4	Mendoza	VIII
30- 5-1929	34.9	68.0	40	6.5	Sur Mendocino (Mendoza)	VII
24-12-1930	24.7	66.3	30	6.0	La Poma (Salta)	VIII
11- 6-1934	33.7	64.5	30	6.0	Sampacho (Córdoba)	VIII
22- 5-1936	32.5	65.9	40	6.2	San Francisco (San Luis)	VIII
3- 7-1941	31.7	67.9	70	6.7	Caucete (San Juan)	VII
15- 1-1944	31.4	68.4	30	7.8	San Juan	IX
25- 8-1948	24.9	64.8	50	7.0	Salta	VIII
18-12-1949	54.1	70.5	30	7.8	Tierra del Fuego	VII
11- 6-1952	31.7	68.9	30	7.0	La Rinconada (San Juan)	VIII
24-10-1957	28.9	68.0	37	6.0	Villa Castelli (La Rioja)	VII
12- 5-1959	23.2	64.7	100	6.8	San Andrés(Salta)	VII
21-10-1966	27.8	67.5	30	5.0	Belén (Catamarca)	VII
19-11-1973	24.8	64.6	40	6.1	Salta	VII
17- 8-1974	23.3	64.4	30	5.0	Orán (Salta)	VII
23-11-1977	31.3	67.7	40	7.4	Caucete(San Juan)	IX

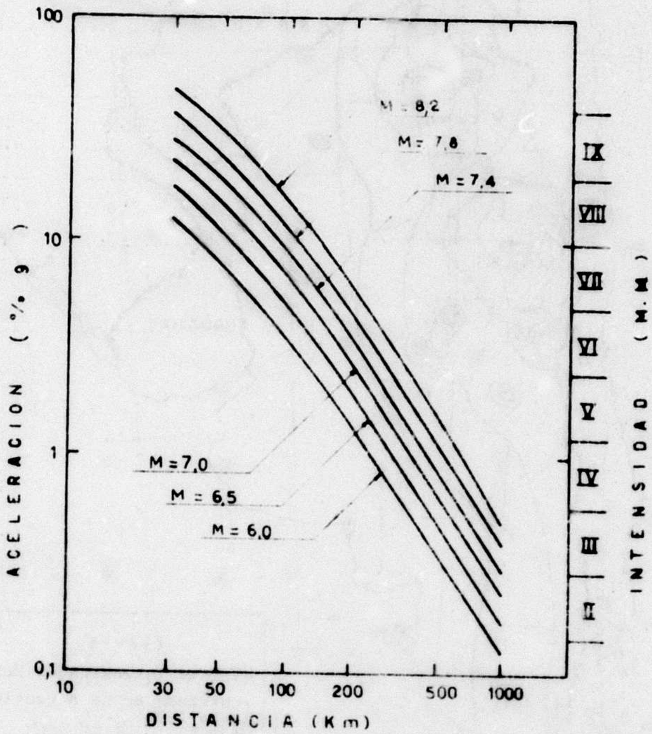


FIGURE II-7
ACCELERATION AND INTENSITY VS. DISTANCE, FOR GIVEN MAGNITUDES
(INPRES, 1978)

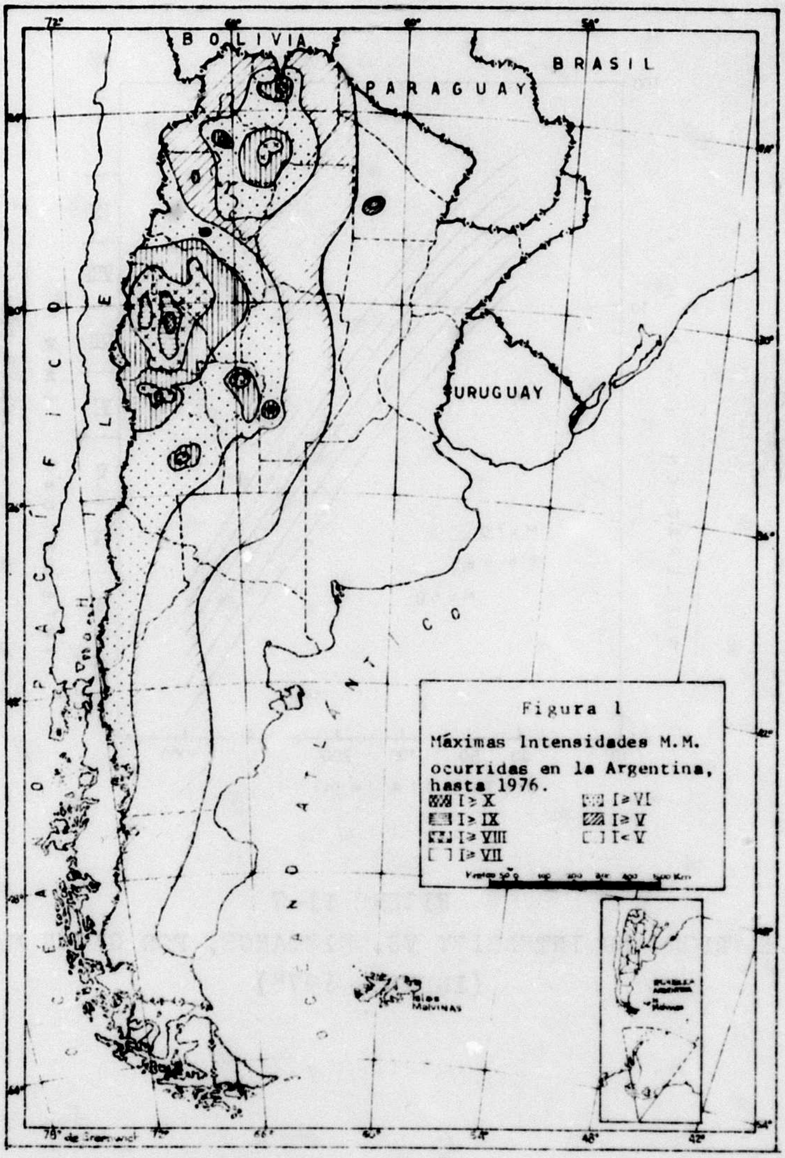


FIGURE II-8

MAXIMUM INTENSITIES OBSERVED IN ARGENTINA UNTIL 1976 (INPRES, 1978)

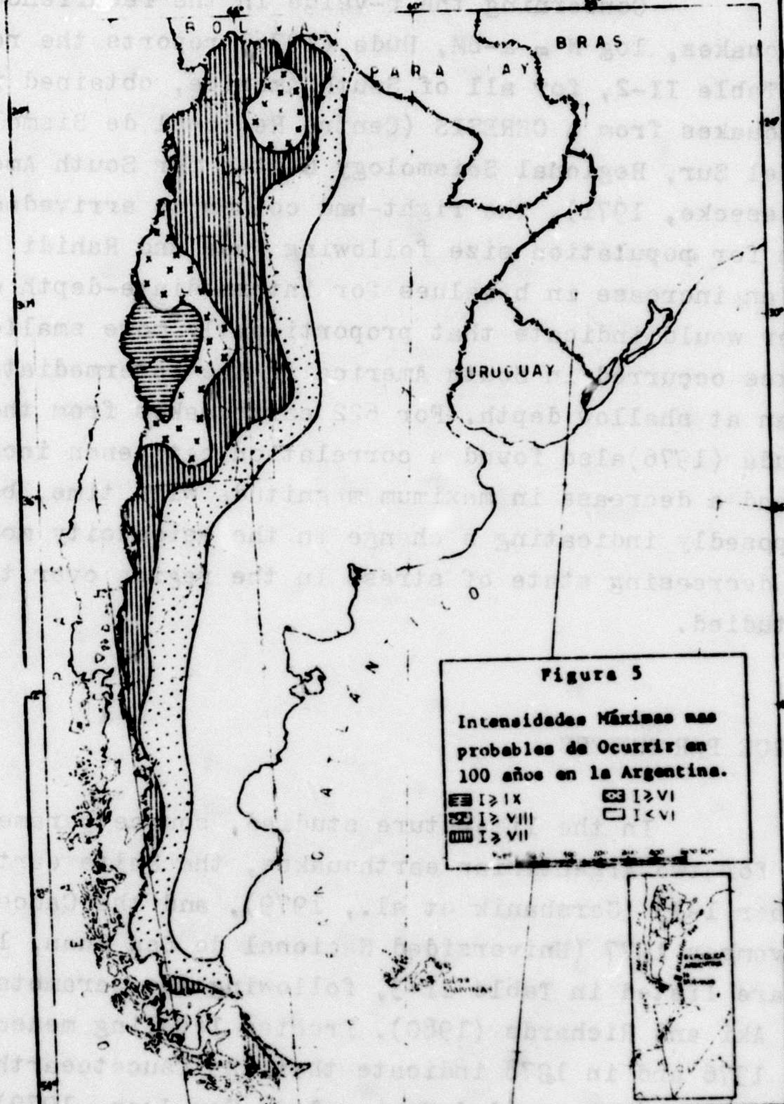


FIGURE II-9

SEISMIC RISK MAP FOR ARGENTINA (INPRES, 1978)

Concerning the b-value in the recurrence relation for earthquakes, log N = a-bM, Duda (1976) reports the results compiled in Table II-2, for all of South America, obtained from data of 381 earthquakes from a CERESIS (Centro Regional de Sismología para América del Sur, Regional Seismology Center for South America) catalogue (Giesecke, 1971). The right-hand column is arrived at by compensation for population size following Duda and Rahidi (1972), and suggests an increase in b-values for intermediate-depth earthquakes. The latter would indicate that proportionally more small-magnitude earthquakes occurred in South America in the intermediate depth range than at shallow depth. For 622 earthquakes from the same catalogue, Duda (1976)also found a correlation betweenan increase in b-value and a decrease in maximum magnitude with time, both phenomena supposedly indicating a change in the seismicity mode, possibly due to a decreasing state of stress in the region over the time interval studied.

D. SOURCE PARAMETERS

In the literature studied, source parameters were reported for two Argentinian earthquakes, the Salta earthquake of 19 November 1973 (Gershanik et al., 1979), and the Caucete earthquake of 23 November 1977 (Universidad Nacional de San Juan, 1979). The results are listed in Table II-3, following the parameter definition given by Aki and Richards (1980). Precise leveling measurements taken in 1976 and in 1978 indicate that the Cauceteearthquake caused a 1.14 m uplift (Universidad Nacional de San Juan, 1979). Other measurements suggest also a gradual uplift of approximately 4.4 cm over the period 1967-1976, according to the same reference.

TABLE II-2

b-VALUES FOR SOUTH AMERICAN EARTHQUAKES SOUTH OF 10^{o}N, 1960 - 1969, $5.5 \leq m_b \leq 8.5$ (after Duda, 1976)

number of earthquakes	depth range (km)	b-value	
		normal	compensated[1]
381	all depths	0.99	0.99
297	< 100	1.08	1.2
63	100 - 450	1.09	1.5
21	> 450	0.48	1.2

[1]compensated for population size (Duda and Rahidi, 1972)

TABLE II-3
SOURCE PARAMETERS FOR TWO ARGENTINIAN EARTHQUAKES

earthquake name	Salta[2]	Caucete[3]
date	19 Nov 73	23 Nov 77
origin time	11:19:35	03:26:25
latitude	24.7°S	31.7°S
longitude	64.6°W	68.9°W
depth (km)	40	40
m_b	5.8	7.3
M_s	5.9	-
strike	N76°W	N47°W
dip	60°	70°
plunge	-	65°
seismic moment (erg)	1.33×10^{26}	2.16×10^{27}
stress drop (bar)	37.3	8.75
displacement (cm)	50	120
fault length (km)	11.5	120

[1]Parameter definition according to Aki and Richards (1980)
[2]Gershanik et al., 1979
[3]Universidad Nacional de San Juan, 1979; INPRES, 1977

E. PROPAGATION VELOCITIES

Little literature has been found on regional propagation velocities. Volponi (1968) composed a propagation velocity structure near Mendoza, based on S-P travel time differences for a series of four earthquakes occurring very shortly in succession at 32.8°S, 68.9°W on 21 October 1968 (Figure II-10a). In this article, Volponi suggests that velocity structures in the upper part of the crust may be more complex than indicated. This seems evidenced by refraction survey data just East and South of Tucumán Province, reported by Zossi (1979), resulting in the structure of Figure II-10b.

F. NOISE CHARACTERISTICS

Volponi and Mendiguren (1963) studied short-period mean noise amplitudes over a 100x25 km area near San Juan, using 1-second instruments at eight sites (Figure II-11). Despite the short distances between sites, there is considerable noise amplitude difference: 1 - 75 mμ, not counting site 8 which shows mainly traffic noise. This is due basically to geological differences. For instance, sites 3 (aluvium) and 7 (precambrian rock) are less than 15 km apart, but show a 30 dB difference in noise level. The dominant noise period in this experiment varied between 0.5 and 1.0 seconds.

Short-period noise levels measured on the vertical component of the WWSSN station at La Plata (LPA) typically vary between 160 and 500 mμ, with dominant periods of 1 and 2 seconds, respectively (Figure II-12). Long-period noise levels at this station, measured on the horizontal North component (Figure II-13) vary between 4 and 16 μ, with dominant periods of 5 and 90 seconds, respectively, in which the former are superimposed on the latter. The station is located near an urban area over sediment, which probably explains the noise characteristics observed.

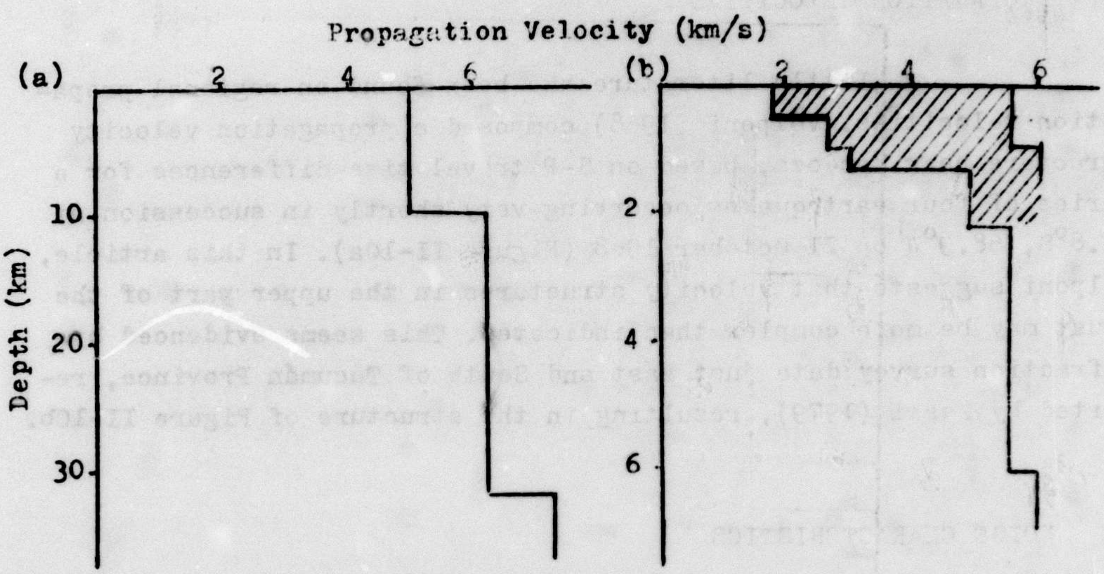


FIGURE II-10

PROPAGATION VELOCITY STRUCTURES IN ARGENTINA

(a) Mendoza: 31-33°S, 68-71°W. After Volponi (1968).

(b) Near Tucumán Province: 26-28°S, 64-65.5°W. After Zossi (1979). Hatched area indicates velocity variation.

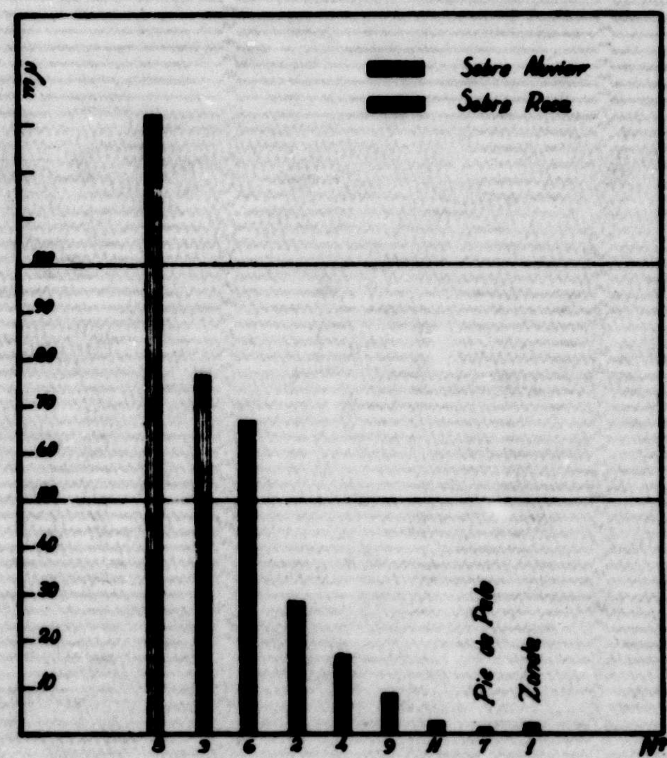


FIGURE II-11

MEAN SHORT-PERIOD NOISE AMPLITUDES ABOUT 1 HZ, MEASURED AT EIGHT SITES WITHIN 100 X 25 KM AREA NEAR SAN JUAN (Volponi and Mendiguren, 1963)

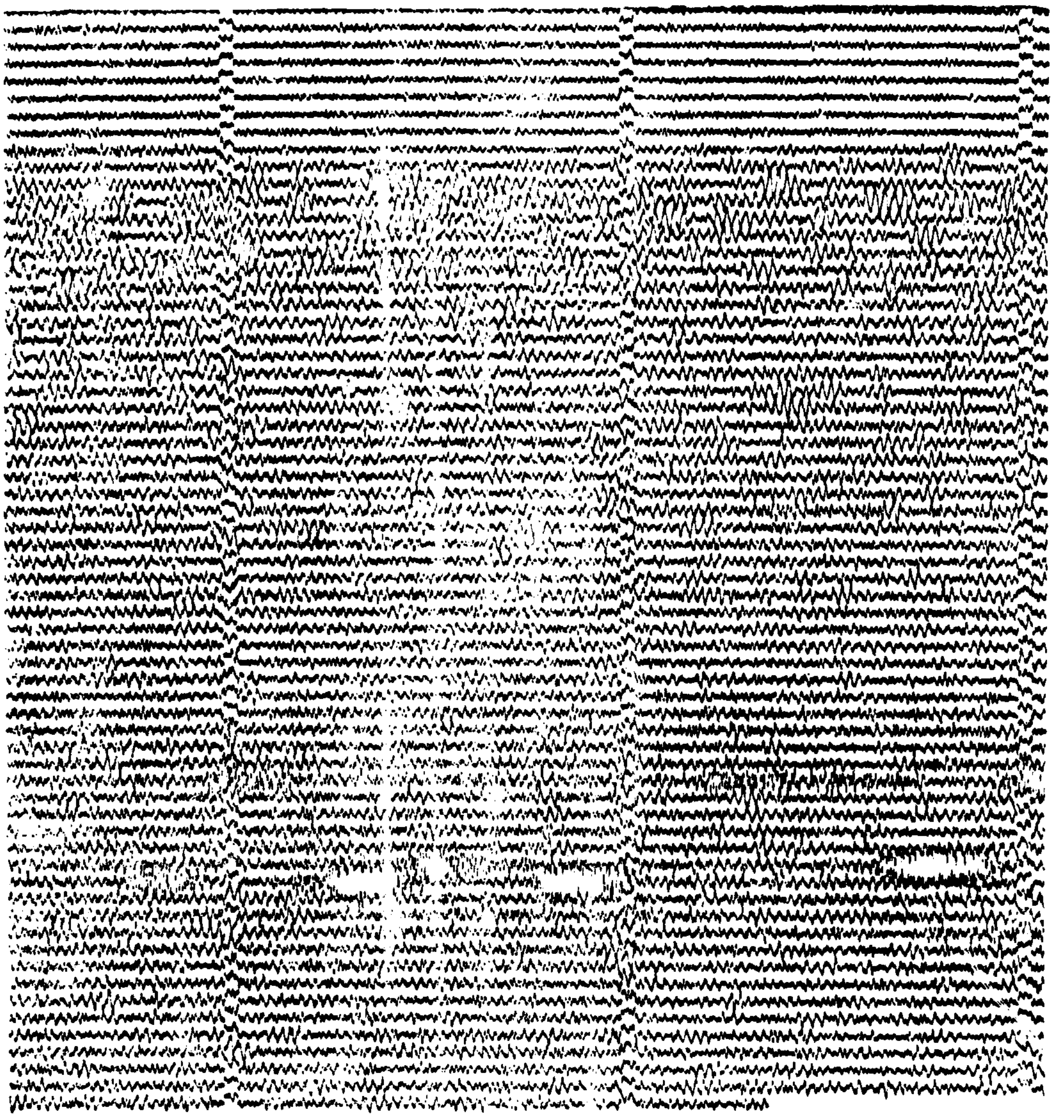


FIGURE II-12

VERTICAL COMPONENT, SHORT-PERIOD NOISE SAMPLE FROM STATION LPA

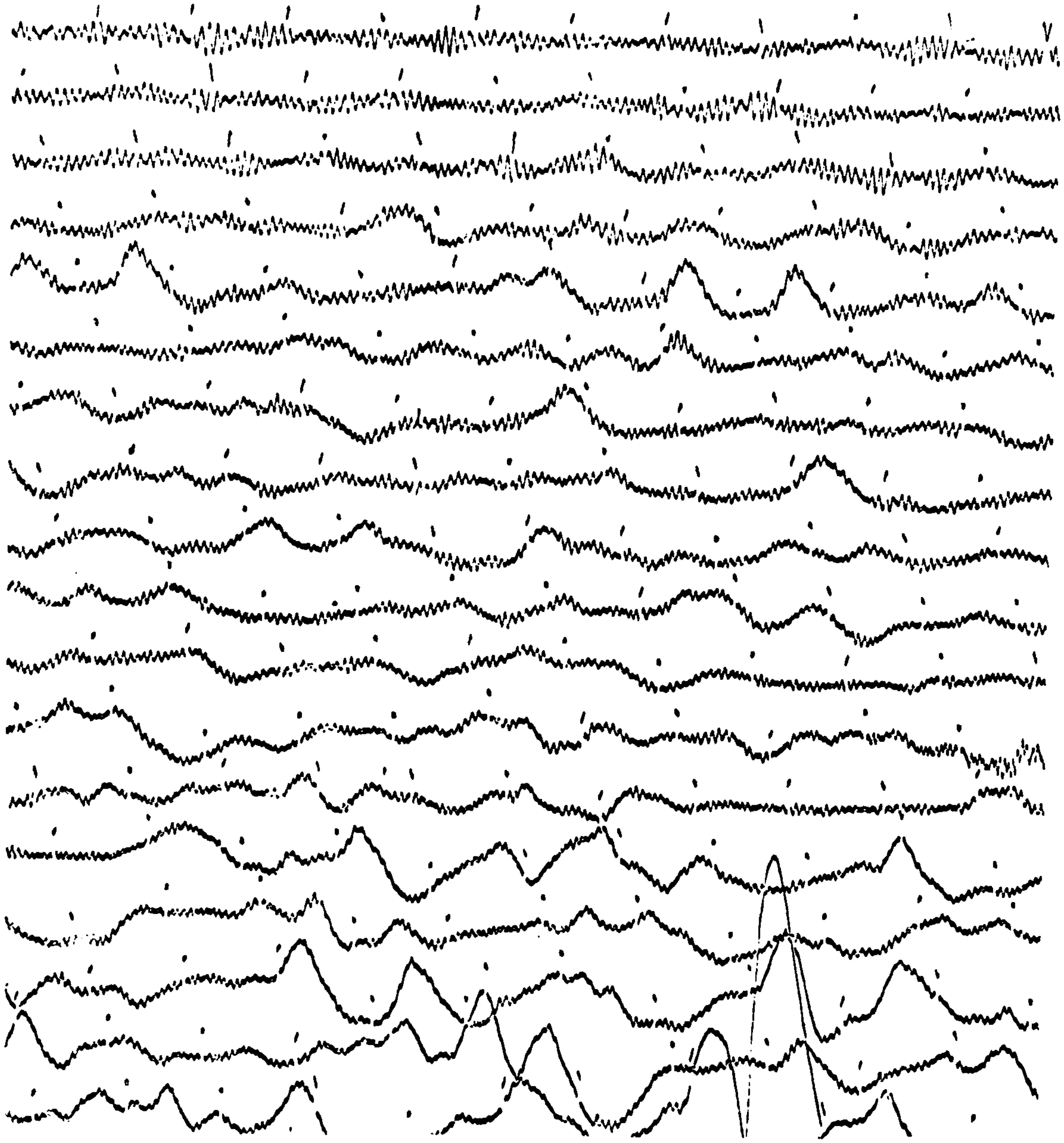


FIGURE II-13
HORIZONTAL NORTH COMPONENT, LONG-PERIOD NOISE SAMPLE FROM STATION LPA

Triepp (1977) studied the spectra of micro-seismic storms registered with a horizontal E-W component, 50-second seismograph at the seismic station ZON ($31^\circ 33'$S, $68^\circ 41'$W) near San Juan. An example is given in Figure II-14. Spectral peaks, some very pronounced, seem to occur mainly between 5 and 10 seconds periods.

G. SIGNAL CHARACTERISTICS

In an initial attempt to study characteristics of regionally recorded seismic event signals, analog seismograms, recorded at the station CEN (Cerro Negro, $31^\circ 34' 33.0''$S, $68^\circ 45' 15.0''$W, elevation 900 m), and containing the primary waves of some Eurasian and Nevada Test Site (NTS) events, were obtained from the Seismological Institute ZONDA of the University of San Juan. NORSAR single-site recordings of the P-waves of these events were studied by the principal investigator in previous rsearch concerning the automatic detection, timing and identification of seismic event signals (Unger, 1978a). The event details are listed in Table II-4, reproduction of the CEN seismograms is attempted in Figure II-15. For comparison,the corresponding NORSAR recordings and their associated envelopes are presented in Figure II-16.

Three items of interest were analyzed: travel time and wave identification, first motion, and secondary signal onsets. The results are combined, and compared with readings from the NORSAR records, in Table II-5.

The significant primary signals of Eurasian events received in Argentina, epicentral distance $\Delta = 140^\circ - 160^\circ$, are PKP waves, those of the NTS events, $\Delta = 82^\circ$, short-period P-waves. The travel times of these waves correspond well to standard travel time vs. distance curves.

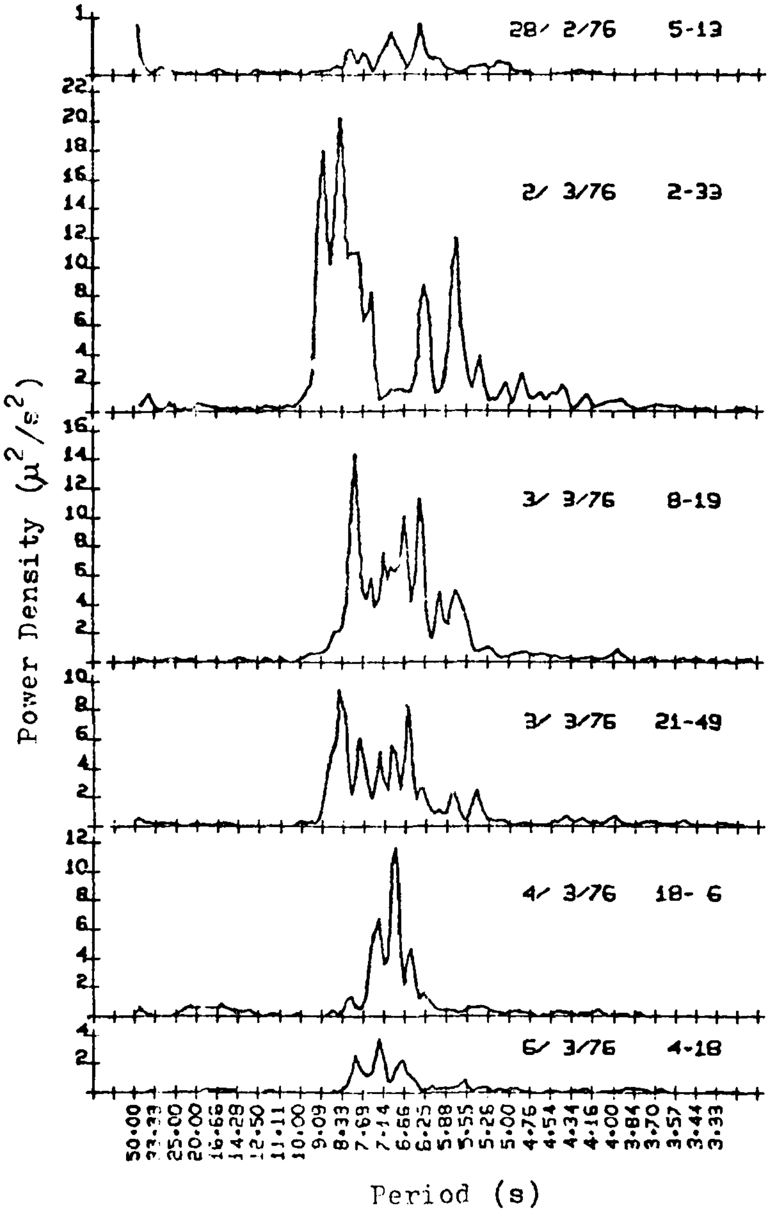


FIGURE II-14

LONG-PERIOD MICRO-SEISMIC STORM SPECTRA (TRIEP, 1977)

TABLE II-4

EURASIAN AND NTS EVENTS USED IN ARGENTINIAN SIGNAL CHARACTERISTICS STUDY

Event Number[1]	Date (m/d/y)	Origin Time (h:m:s)	Place	Latitude (°N)	Longitude (°E)	Depth (km)	m_b	Classification[2]
21	09/06/71	13:37:11.0	Kurile Is.	46.7	141.4	29	6.1	Q
22	09/09/71	23:01:06.0	Kurile Is.	44.4	150.9	7	6.0	Q
87	01/20/75	17:31:10.6	Japan	35.0	141.2	28	5.9	Q
90	05/04/75	09:31:59.5	Japan	37.1	142.1	24	5.8	Q
53	12/10/72	04:27:08.4	E.Kazakh	50.1	78.8	0	6.0	E
58	12/10/72	04:26:57.7	E.Kazakh	49.8	78.1	0	5.7	E
60	08/15/73	01:59:58.0	S.Kazakh	42.7	67.4	0	5.3	P
11	08/30/74	15:00:00.0	NTS	37.2	-116.0	0	5.8	N
15	07/08/71	14:00:00.0	NTS	37.1	-116.0	0	5.5	N

[1] same as in Unger (1978a)

[2] Q - Eurasian earthquake

E - Eastern Kazakh presumed underground nuclear explosion

P - Russian presumed peaceful underground nuclear explosion

N - Nevada Test Site (NTS) presumed underground nuclear explosion

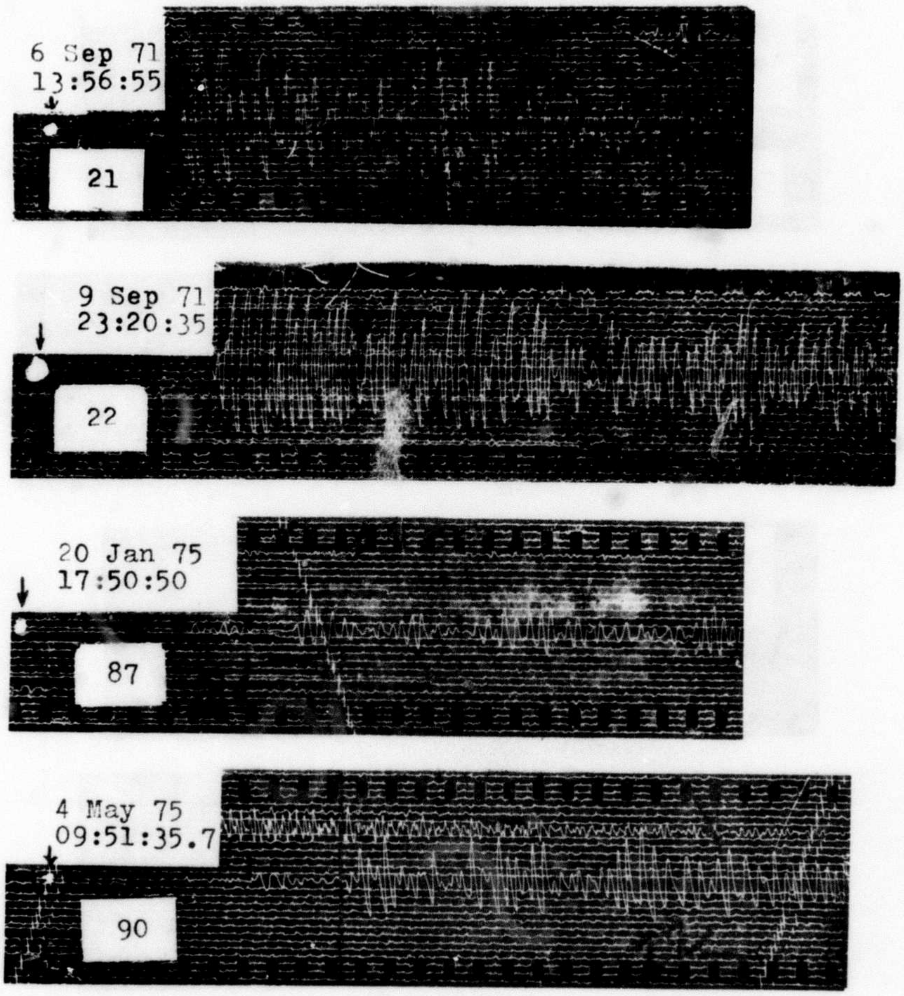


FIGURE II-15 (Page 1 of 2)
STATION CEN SEISMOGRAMS FOR EURASIAN AND NTS EVENTS

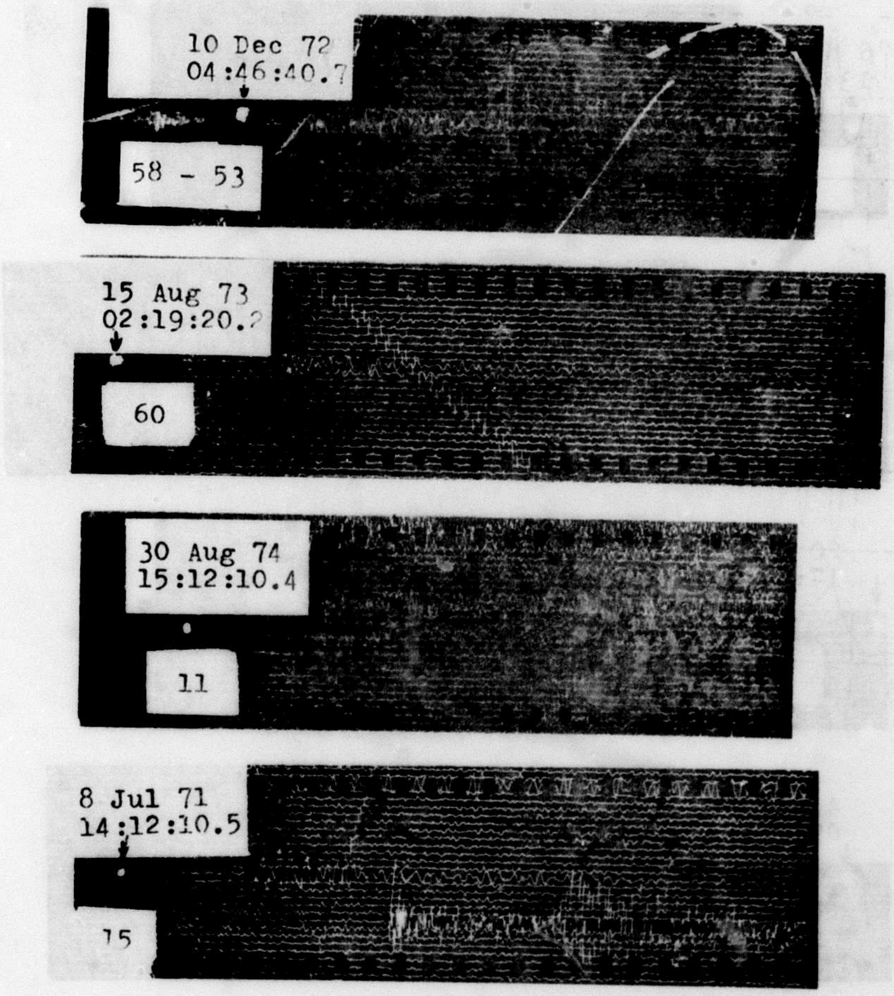
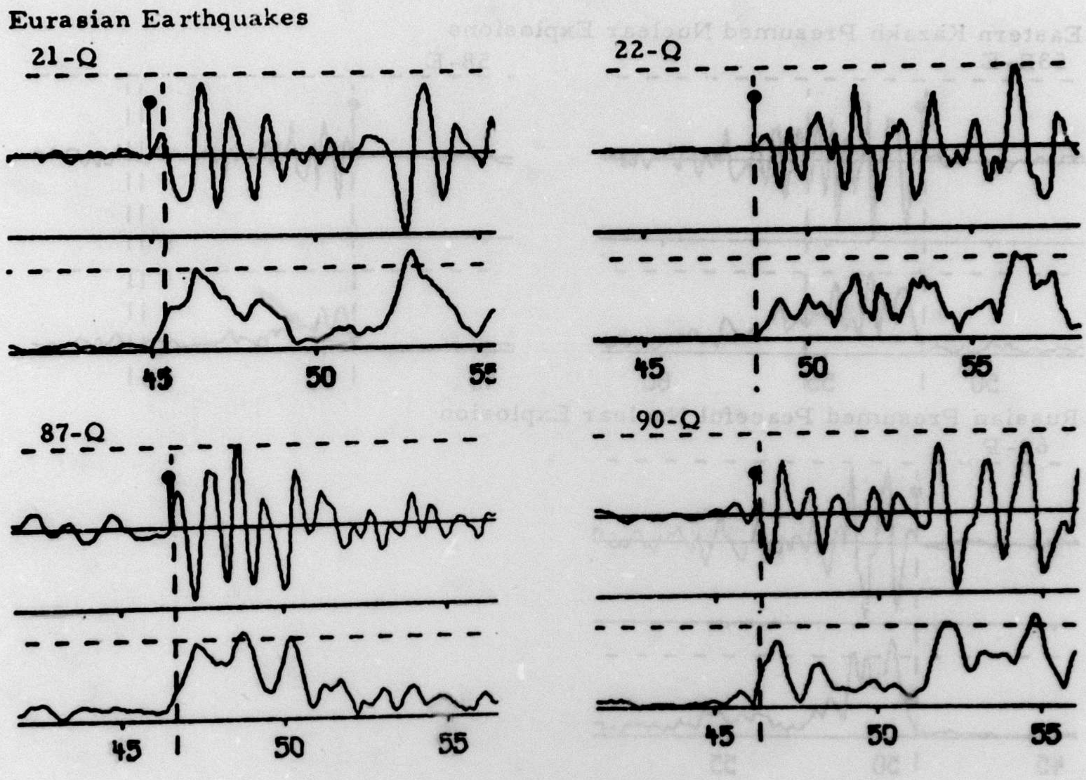


FIGURE II-15 (Page 2 of 2)
STATION CEN SEISMOGRAMS FOR EURASIAN AND NTS EVENTS



Relative Time (s)

FIGURE II-16 (Page 1 of 2)

NORSAR SINGLE-SITE SEISMOGRAMS AND ENVELOPES OF EURASIAN AND NTS EVENTS, WITH ANALYST (↑) AND AUTOMATIC (¦) SIGNAL ONSET TIMING (Unger, 1978a)

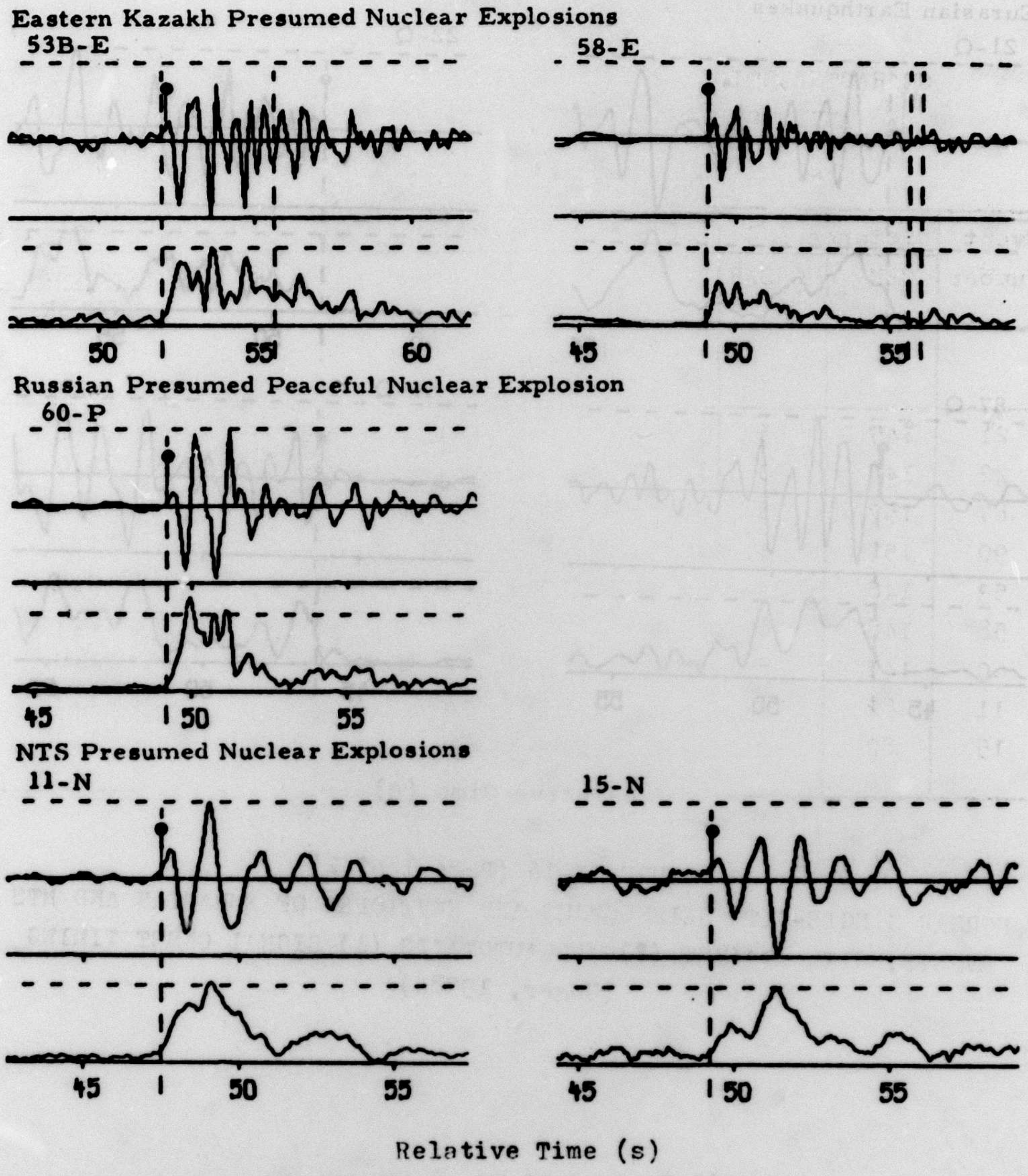


FIGURE II-16 (Page 2 of 2)

NORSAR SINGLE-SITE SEISMOGRAMS AND ENVELOPES OF EURASIAN AND NTS EVENTS, WITH ANALYST (⚲) AND AUTOMATIC (¦) SIGNAL ONSET TIMING (Unger, 1978a)

TABLE II-5

CHARACTERISTICS OF PRIMARY SIGNALS FROM EURASIAN AND NTS EVENTS, RECORDED IN ARGENTINA

Event Number	Distance (°) CEN	Distance (°) NORSAR	CEN Signals Travel Time (m:s)	CEN Signals Wave Identification	First Motion CEN	First Motion NORSAR	Secondary Signal Delays (s) CEN	Secondary Signal Delays (s) NORSAR
21	147	65	19:05.8	PKP	+	+	1.8	1.0
22	147	70	19:43.9	PKP	-	+	1.2	1.0
87	157	76	20:01.4	PKP	+	+	1.5	1.5
90	157	74	20:00.0	PKP	-	+	0.8	1.2
53	148	38	19:51.8	PKP	+	+	0.8	0.8
58	148	38	19:52.8	PKP	+	+	1.2	0.7
60	147	38	19:35.4	PKP	-	+	1.7	1.0
11	82	73	12:20.9	P	-	+	1.4	1.3
15	82	73	12:21.3	P	-	+	1.4	1.3

For both NTS presumed underground explosions, P-wave first motion on the Argentinian records is negative, contradictory to the expectation of uniform compressional first motion radiation for an underground explosion source model (Dahlman and Israelson, 1977). First motion is positive on the corresponding NORSAR records. A possible explanation is tectonic strain release associated with explosions (Rodean, 1980), resulting in compression at some stations and dilatation at others, depending on the tectonic strain release radiation pattern. In this respect, it may be of interest to note that the NORSAR and CEN azimuths from the NTS differ by approximately 90°, so that first motion would indeed be likely to be different at the two stations. Naturally, this hypothesis would have to be further tested with a statistically sufficient signal population. Because of uncertainty in core boundary effects, interpretation of PKP-wave first motion information has been omitted in this study.

The onset of secondary signals is relevant in event identification, in part since they may be depth phases giving information about source depth, and in part because the relation between the relative amount of multiple signals, or pulse complexity, and signal frequency seems a strong contributor in multi-variate discrimination (Sax et al., 1978; Sax and Unger, 1980; Unger, 1978a; Unger, 1980). In the NORSAR recordings, secondary signal onset determination was aided by the accompanying traces of the instantaneous amplitude or envelope; in the CEN recordings, secondary signal onsets had to be determined from apparent signal phasing or interference in the raw seismograms. Therefore, it is possible that secondary signal onsets in the CEN seismograms may have gone undetected. The NORSAR and CEN recordings of the NTS P-waves show good coincidence in secondary signal delays (Table II-5). However, only two of the seven Eurasian events, 87 and 53, show coincidence in secondary signal delays among the CEN PKP-waves and the NORSAR P-waves, suggesting that secondary signal delay information may be changed or lost at the core boundary. In view of the above, and naturally also because of the lower possibility of detection, PKP waves are expected to be only of limited value in event identification.

Concerning both teleseismic and regional signal detection, Figure II-17 shows an INPRES detection bulletin for one of its stations, reflecting in general good P- and S-wave detection. Apparently, no other phases are identified in this bulletin.

Finally, in the literature, Sacks and Snoke (1977) report the arrival of seismic waves between P- and S-waves at South American stations from large, regional deep-focus earthquakes. They interpret these to be sp and ps waves, i.e., waves which convert from S to P and from P to S, respectively, upon refraction across an approximately horizontal interface at a depth of 400 km. Based on an apparent velocity reversal, they suggest that this discontinuity may be the lithosphere-asthenosphere boundary.

H. AUTOMATIC SIGNAL DETECTION, TIMING AND IDENTIFICATION

In view of possible future application to Argentinian seismology, research performed previously by the principal investigator, and concerning the automatic detection, timing and identification of seismic event signals (Unger, 1978a, 1978b) was refined and consolidated in two presentations (Sax and Unger, 1980; Unger, 1980). The latter has been prepared for publication.

This research emphasizes the quantification of the essential time-domain information of seismic waveforms and its use in achieving the above mentioned objectives. It is shown that an efficient automatic envelope detector and timer for short-period signals can be designed. This detector can be equipped with a

I M P R E S

INSTITUTO NACIONAL DE PREVENCION SISMICA

SAN JUAN ARGENTINA

LECTURAS PROVISORIAS DE LA ESTACION SISMOLOGICA

"TANTI" - TCA - CORDOBA - R. Arg.

Mes: MARZO Año: 1980

Coordenadas: Latitud -31° 20' 19"

Longitud 64° 35' 27"

Instrumentos: S - 13 SP - (Z; N-S; E-W) T_s = 1 seg.

T_g = 1 seg.

DIA	COMPONENTE	FASE	MOV.	HORA MIN. SEG. (GMT)	OBSERVACIONES
08	SP Z	iP	+	07-01-34.5	
	SP N-S	S		02-26.2	
09	SP Z	eP	-	22-58-11.0	
	SP E-W	S		59-53.5	
11	SP Z	eP	+	01-00-08.0	
12	SP Z	eP	-	09-56-34.2	
	SP N-S	S		57-12.0	
14	SP Z	eP	-	14-10-40.5	
	SP N-S	S		11-15.0	
15	SP Z	eP	+	01-29-24.0	
	SP Z	eP	+	04-01-00.5	
	SP E-W	S		02-18.5	
16	SP Z	eP	-	18-53-17.2	
	SP E-W	S		54-26.5	
17	SP Z	(e)P		15-53-49.0	
	SP E-W	S		54-26.0	
19	SP Z	iP	-	01-13-26.8	Δ = 10 Km
	SP N-S	S		29.8	
	SP Z	eP	-	14-57-34.5	
	SP N-S	S		58-50.5	
20	SP Z	eP	(+)	22-53-17.5	
	SP N-S	S		56.5	
21	SP Z	iP	-	22-02-06.0	
	SP N-S	S		41.5	
22	SP Z	eP	-	02-11-07.8	
	SP Z	eP	+	02-26-41.0	
25	SP Z	iP	-	00-52-33.9	
	SP N-S	S		53-34.0	
	SP Z	eP	-	22-04-57.0	
	SP N-S	S		36.8	
28	SP Z	eP	-	01-27-46.2	
	SP Z	S		28-27.8	
	SP Z	iP	+	09-34-58.0	

FIGURE II-17

INPRES DETECTION BULLETIN FOR STATION TCA

controllable false alarm rate, based on a Gaussian noise model. Well-dispersed long-period surface waves may be detected by means of statistical phase bias observation.

For Eurasian events, short-period phase and frequency related identification parameters (pulse complexity and mean instantaneous frequency), produced automatically by the envelope detector, are believed to show an inverse relation between the size and the amount of tectonic energy release ruptures; the ruptures triggered by explosions then appear to be smaller than the spontaneous ruptures in earthquakes.

SECTION III
CONCLUSIONS AND FUTURE WORK

A literature orientation on regional seismology in Argentina, and an initiation of a study on noise and signal characteristics have been presented.

Existing and projected research facilities, including seismometry, digitizing of data, and modern computing facilities, together with active regional seismic phenomena, form a strong basis for future work. Most of the seismicity is explained in terms of tectonic movement. However, for instance, the apparent seismicity gap in Tucumán Province and absence of seismic activity at depths between 350 and 500 km, the seemingly horizontal part of the subduction of the Nazca Plate under the South American Continent, and the depth of the lithosfere-asthenosphere boundary are items suitable for further investigation.

If feasible, moment tensor program application to the regional and teleseismic signals of Argentinian events could augment considerably the knowledge of regional source parameters and propagation phenomena. It then would be interesting to correlate signal and source characteristics through automatic signal parameterization.

Noise characteristics confirm the relatively high amplitude levels of stations located over sediment and aluvium, in contrast to levels of a few mμ for hard rock sites. Local differnces may be as much as 30dB. Micro-seismic stroms seem to have their long-period energy mainly between 5 and 10 second periods.

Characteristics of teleseismic signals received in Argentina from Eurasian and NTS events show negative first motion on the NTS P-waves, and possible changes due to the P to PKP wave conversion at the core boundary as evidenced by secondary signal onsets. The former may indicate tectonic strain release associated with underground explosions.

Under continued research, installation of a digital station with automatic signal detection and recording are projected. The feasibility of automatic signal parameterization according to an international data format will be studied, and local noise measurements may be tested against a Gaussian noise model, for false alarm rate control of the automatic detector.

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